



Sandia
National
Laboratories



Flow Visualization and Processes Laboratory

Automated Multiscale Permeameter

Need

Detailed information about the physical characteristics and material properties of the geologic medium is required to solve many of the applied problems routinely encountered in the petroleum, environmental, mining, and geotechnical engineering industries. The acquisition of such information through characterization activities is complicated by the fact that many of the important material properties are measured at scales much smaller than can be accommodated in current predictive models. For this reason, upscaling models are required for transforming information from the scale of the available data to the computational grid block scale. Numerous upscaling theories, representing a wide diversity of approaches, have been proposed; however, actual physical data to support these theoretical models are sparse and limited in scope.

Description

The Flow Visualization and Processes Laboratory performs systematic physical investigation of permeability upscaling using a specially adapted mini-permeameter that we have termed the Automated Multiscale Permeameter (AMP) (Tidwell and Wilson, 1996). The AMP allows rapid, nondestructive, and precise measurement of rock matrix permeability at multiple sampling scales. A key feature of the AMP is its ability to acquire measurements at different scales according to consistent boundary conditions and flow geometry.

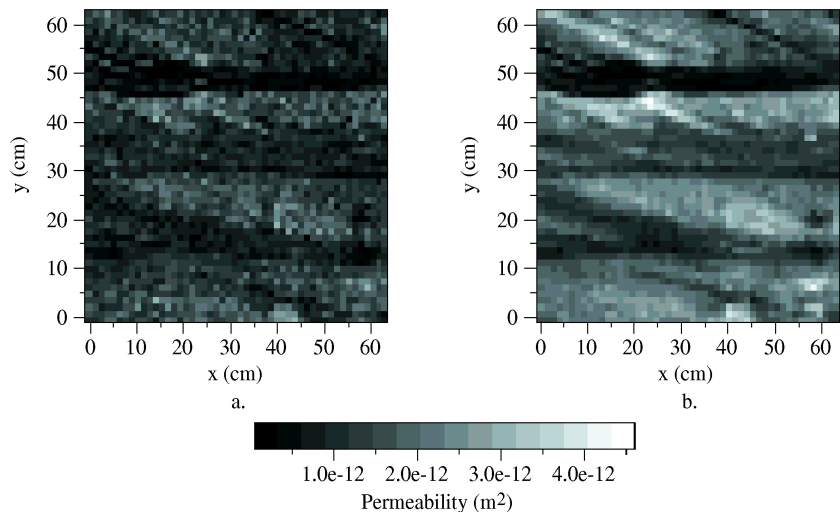
Measurements are made by compressing the permeameter tip-seal against a rock surface and injecting gas into the rock while measuring the flow rate and gas pressure from which the permeability is calculated using a modified form of Darcy's Law. The permeameter consists of four mass-flow meters of varying sensitivity, a pressure transducer, a barometer, and temperature sensor that are connected to a regulated source of compressed nitrogen (permeability range of 1×10^{-15} to 1×10^{-9} m²). A series of specially designed tip-seals, the diameter of which defines the scale of measurement, are used to establish a known boundary condition on the rock surface. Thus, by changing the size of the tip-seal, the permeameter examines volumes of rock ranging in scale from tenths to thousands of cubic centimeters. A soft, durable silicone rubber establishes the seal between the injection nozzle and the



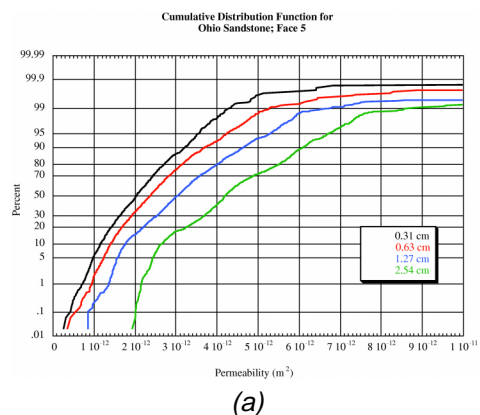
Photo of a single block face (1.1 x 1.0 x 0.98 m) of Massillon sandstone (fluvial origin).

rock surface. To improve measurement precision and facilitate data collection, the gas permeameter has been automated for laboratory use. Specially adapted PC-based software controls operation of the electronic permeameter instruments and solenoids. An x-y positioning system coupled with a pneumatic piston has also been automated for positioning and compressing the permeameter tip-seal against the rock surface. The system allows more than 300 measurements to be made in an eight hour period, unattended.

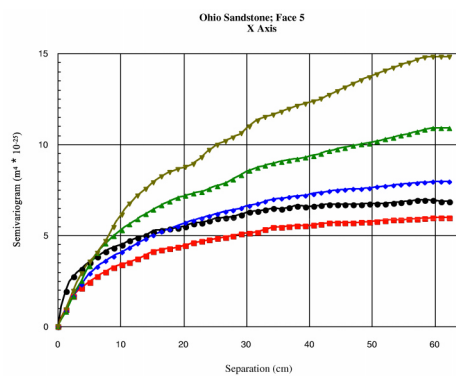
Permeability upscaling is investigated by collecting large suites of permeability data over a range of discrete scales from blocks of rock (Tidwell, 1994). Systematic investigation of the influence of key porous media characteristics on upscaling behavior is approached through the careful selection of rock samples for analysis. For example, samples exhibiting different spatial structure (e.g., a massive, laminar bedded and cross-bedded samples) are investigated and the results compared. Ultimately, the measured data are used to test theoretical upscaling models and models of spatial variability.



2-D permeability fields measured from the Massillon sandstone using a) 0.6 cm, and b) 2.5 cm OD tip-seal. Note the distinct smoothing of the fields as the measurement scale is increased.



(a)



(b)

(a) Cumulative distribution functions measured from the Massillon sandstone using the tip-seals measuring 0.6, 1.27, 2.5, 5.1, and 10.2 cm OD. Note the increasing mean with increasing measurement scale. (b) Semivariograms measured from the Massillon sandstone using tip-seals measuring 0.6, 1.27, 2.5, 5.1, and 10.2 cm OD. Note the increasing range with increasing measurement scale.

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